RC 1 - Response

De Donker et al. present a novel and ambitious inverse methodology to infer maps of erosion rates from mineralogical data derived from XRD analysis of suspended sediments. Their method defines a model matrix, which uses bedrock mineralogy data also from XRD analysis and a geological map to characterise the catchment, and then uses a non-linear inversion to infer erosion rates based on the mineralogical data of the suspended sediments. They provide a thorough analysis of the inversion method, including testing two different inverse schemes, as well as testing a wide range of various parameter values to explore their limitations. Having done this, they then apply their method to the Gornergletscher catchment, presenting an erosion rate map for the area. Generally I found the manuscript to be well written, and will likely be suitable for publication following some further exploration/explanation of the limitations of the inversion.

General comment: We thank the reviewer for the positive and constructive feedback, for the attentive reading of our manuscript and for the helpful suggestions.

Firstly, I think the authors do an excellent job of acknowledging and testing many of the limitations of the inversion, and so I commend them for this. However, I found some of the presentation of the scatter plots in figures 7-10 to be slightly unintuitive. It would be really helpful, perhaps in a supplement, or alongside these figures, that the resulting erosion rate maps of the synthetic tests are shown. Of course, it would be nice to see all of them, but perhaps 3 for each parameter tested would aid the reader in understanding how different the inversion result can be. For example, what do the three erosion rate maps look like for the three different geological map inputs? Perhaps the results are very similar, but at the moment, it is difficult to infer how much variation is possible for the model results based on different inversion parameters being changed.

Reply: We have now provided the resulting posterior erosion maps in Appendix B and refer to them in the main text (l. 285). This allows the reader to see example outputs for each parameter scenario, thank you for the suggestion.

On this note, I perhaps would also like to see a more complex synthetic test set up than the one presented. Something akin to a checkerboard test might be ideal, or a scenario where there are more than one peak in erosion rate. From what I can tell, the present synthetic test has high erosion rates across two similar lithologies (Stockhorn-Turftgrat-Gornergrat and ZSF ophiolites?), and low rates elsewhere. This is quite a simple set up. Would the inversion scheme be able to identify two different peaks of erosion that are spatially discrete within these two units? What about three peaks spread out across the catchment? Hence, I would like to see a slightly more complex synthetic erosion rate map tested. Having said this, I did like the testing of two different inversion schemes on the synthetic data to decide which one is more suitable – nice analysis.

Reply: We have added a test using a true erosion map with three Gaussian peaks in Appendix A and refer to it in the main text (l. 281–282). This demonstrates the limitations of the lithological setup clearly. We did not implement a checkerboard pattern, as it would conflict with the smooth erosion-domain assumption.

Finally, I felt that the XRD data needed explaining a little better and perhaps slightly more exploration of the associated errors. For instance, the number of bedrock XRD analyses is not stated. I wondered whether if only one per lithology were analysed, how different two samples from the same lithology could be, and how much error this could introduce? If only one is used per lithology, is the assumption that each mapped lithology is homogenous fair? From what I can tell from the unit descriptions they can be quite variable. How is this variability accounted for? Hence, I would like to firstly see greater detail given for the acquisition of XRD data and mineralogy data, and perhaps some exploration of inversion results akin the analysis presented in figure 8 for an error introduced when the measured bedrock mineralogy is different from the true bedrock mineralogy. Here you could synthesise a sediment mineralogy based on one set of bedrock mineralogies, and then randomly change each mineralogy in the A matrix by some value of the 'error'. I am not sure whether this is reasonable or not however, as I am not an expert in XRD, and I am not sure how the bedrock XRD data was collected.

Reply: We have added error bars on the normalized XRD peak-area data for lithological units where multiple samples were available. These show that, while variability exists between samples, the overall pattern remains consistent. We also included additional details on the source sampling strategy in Section 3.2 to clarify how variability and potential error are accounted for.

One final comment, the introduction is duplicated. One needs to be removed, and the section numbers redone.

 Reply: Thank you for the attentive reading, the duplicate introduction has been removed, and section numbering has been updated accordingly.

I hope the authors find these help to improve the manuscript. I also outline a few line comments below.

Line 61 – Should be an in-text citation.

Reply: Replaced with an in-text citation.

Line 270ish Gorner-gletcher then gornergletcher, needs to be consistent throughout the manuscript.

 Reply: All instances of "Gorner Glacier" and "Gorner-gletscher" have been standardized to "Gornergletscher."

Figure 7. Originial geology – should be original.

Reply: Corrected "Originial" to "Original."

We thank the reviewer again for the constructive suggestions, which have helped improve the clarity and completeness of the manuscript.